Issued February 9, 1915.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
D. W. MAY, Special Agent in Charge,
Mayaguez, P. R.

Bulletin No. 17.

FUNGUS DISEASES OF COFFEE IN PORTO RICO.

BY

G. L. FAWCETT,
Plant Pathologist.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. DEPARTMENT OF AGRICULTURE.

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PORTO RICO AGRICULTURAL EXPERIMENT STATION.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

PORTO RICO AGRICULTURAL EXPERIMENT STATION,
Mayaguez, P. R., Ociober 15, 1914.

SIR: I transmit herewith a manuscript on Fungus Diseases of Coffee in Porto Rico.

The seriousness of these troubles from the standpoint of one of the leading industries of Porto Rico justify the studies herein set forth, and the methods suggested for combating the diseases, which are now causing enormous losses, should be widely disseminated among the planters of the island.

I respectfully recommend that this manuscript be issued as Bulletin No. 17 of this station and that it be published in both English and Spanish.

Respectfully,

D. W. MAY,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Recommended for publication.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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FUNGUS DISEASES OF COFFEE IN PORTO RICO.

INTRODUCTION.

Fungus diseases of coffee are common in Porto Rico, and in many instances destructive. The reduction in the yield and consequent loss which result from their activity are not definitely known, but they must be large. The small crop of many plantations is no doubt due to the constant though often inconspicuous defoliation and killing of the trees which they cause. It is desired not only to attract attention to these diseases, but to suggest such means of getting rid of them as have been shown by experience to be of value. The excellent but costly methods of fighting disease, such as those practiced in the case of the intensively cultivated citrus fruits, are not to be recommended so unhesitatingly for coffee, the profits from which are not so great as to make the cost of production of small importance. Moreover, coffee is often grown in extended plantings in mountainous country where it receives so little cultivation as to be hardly more than a wild plant. Where these conditions exist it is not likely that any more attention will be given the diseases than in the past. But there are other, usually smaller, plantations where it would seem worth while to take advantage of any measures of value in keeping up their present good condition, either by fighting those diseases that have already become established or keeping them from the healthy young plantings.

It is expected also that a publication of this nature will be of value in dispelling the idea entertained by some planters that the diseases of this plant have been so neglected as to be practically unknown, but only await scientific study to be entirely done away with. Some of the coffee diseases of Porto Rico are common to other coffee-growing countries, and were first described many years ago. Suggestions as to their control have been made from time to time by laboratory workers, but apparently the methods have never been tried by growers, else such value as these suggestions possess would have been previously realized. The knowledge of the life history of the parasitic organisms causing the diseases has led to no entirely successful method for their control, if this is taken to mean some way in which the diseases may be very easily eradicated without some expense and careful attention in application.

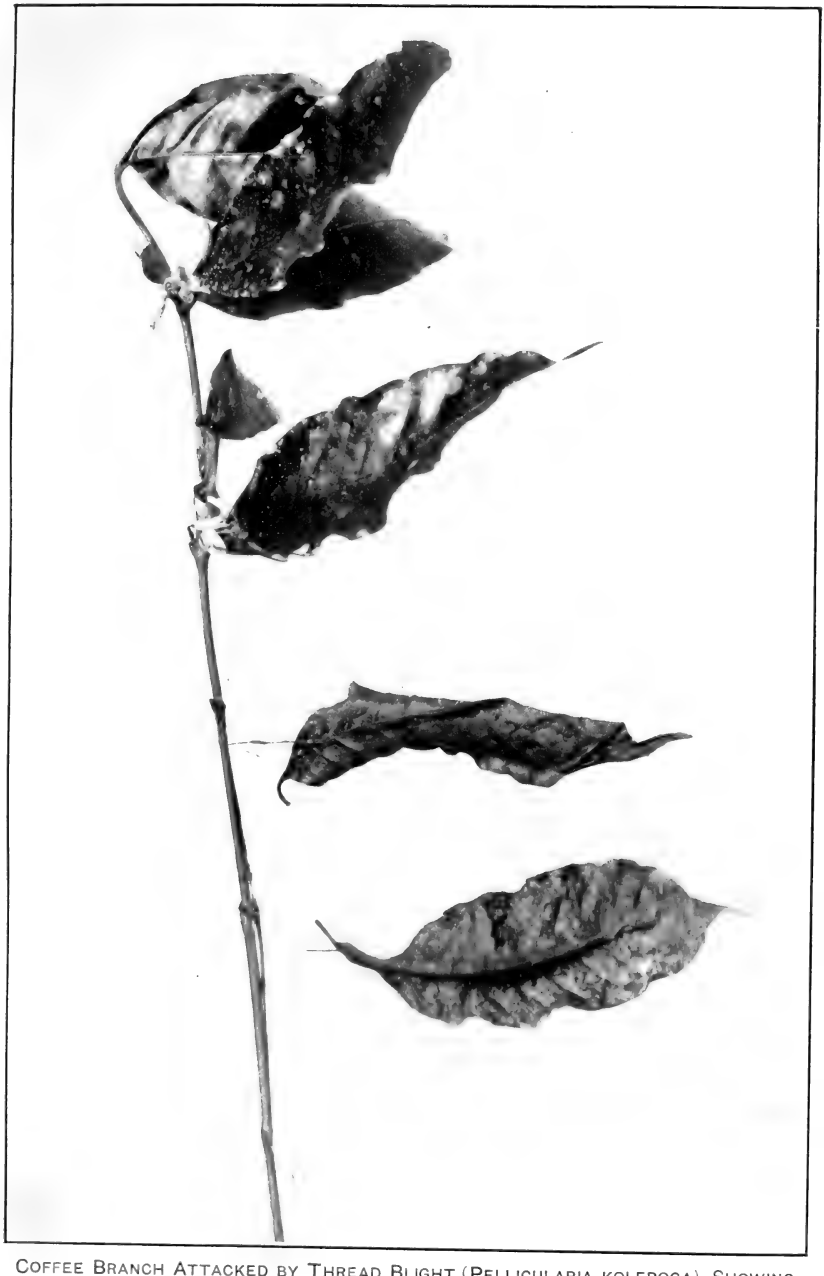
LEAF ROT OR THREAD BLIGHT (*Pellicularia koleroga*).[1]

This is quite common in all plantations except those at higher altitudes. Of all the coffee diseases it is perhaps the most conspicuous, its presence being usually indicated by the blackened leaves which, after having been attacked by the fungus, are held suspended for some time by its threads (Pl. I). It has been reported from various places in India and the East Indies and recently from Surinam, and no doubt is found throughout the coffee-growing regions of the West Indies. A disease similar in character has also been reported from Venezuela, where it is known as "candelillo"; the real leaf rot which has been reported from that country is also known by that name.

On examination, the threads of the fungus which cause the disease will be found on the lower side of the twigs where at each pair of leaves it branches to form a thin web covering their undersurfaces. On the newly attacked leaves this web is white, but later it becomes brown. The leaves on which the fungus has obtained a better foothold and which have turned black often have a finely mottled appearance, due to the thickening of the web at the points where it is attached to the leaf. A further stage is represented by the development of the web into a parchment-like membrane completely concealing the lower side of the leaf. This may be removed with a needle or knife point "like a piece of gold beater's skin." The webs correspond to the feeding form of the fungus, serving to absorb food material from the leaves; the threads to the "traveling" form, by the extension of which along the stems and branches in the course of growth it reaches fresh material on which to feed. The threads which are at first white become brown after a time, break and fall away, but fragments often remain, sometimes concealed by the bark, which serve as new sources of infection. When examined microscopically the dense places are seen to be made up of flattened, much branched threads, which besides acting as holdfasts may also serve to draw food material from the leaf, although the threads which penetrate the leaf soon after it is attacked are probably more important in food absorption. No spores or reproductive bodies have been found in the Porto Rican fungus. The vegetative hyphæ of the webs are much branched and interlaced, the branching being often at right angles. (Pl. VII, C.)

The fungus avoids the sunlight, never growing on those parts of the tree which are exposed to the direct rays. Possibly this habit enables it to live on and injure trees from which the shade has been removed. It must have a moist atmosphere for active growth. During the drier months it remains quiescent, the affected leaves drop off, and the plantation may appear quite free from the disease, but enough of the

[1] See also U. S. Dept. Agr., Jour. Agr. Research, 2 (1914), No. 3, p. 231.



COFFEE BRANCH ATTACKED BY THREAD BLIGHT (PELLICULARIA KOLEROGA), SHOWING CHARACTERISTIC SUSPENSION OF LEAVES BY THREADS OF THE FUNGUS.

COFFEE LEAVES ATTACKED BY THE LEAF SPOT FUNGUS (STILBELLA FLAVIDA).

fungus remains to serve to reinfect the trees when the rains become frequent. Apparently it is favored by high temperatures, as it is less common in the cooler higher elevations where more favorable conditions prevail as to moisture than in the warmer though somewhat drier low lands. It spreads from one part of the tree to another by growth, and in the same way to other plants and coffee trees in contact with the diseased coffee trees. To other trees, however, some distance away it is usually communicated by the fungus-infested leaves dropping or being carried by the wind and adhering to any moist leaf or stem on which they happen to fall, the fungus then sending out threads which securely glue the leaves to their new host. Each such leaf serves as a center of infection. That the diseased leaves can not adhere so well to dried surfaces is one reason for the disease not spreading in dry weather. There is apparently no other way in which this fungus is distributed, and for this reason it would seem to be greatly handicapped in comparison with some spore-bearing fungi. It is, however, so widely distributed and has such a way of appearing suddenly in unexpected places that it would seem as though it possessed some other more effective though unapparent means of distribution.

Besides coffee, the author has found this fungus on sour orange, the wild vines *Luffa ægyptica* and *Cucumis anguria*, and the cultivated ornamentals Hibiscus and Croton. It is probably able to attack these plants only under very favorable conditions, as they usually remain free from the disease even when surrounded by infested coffee trees. The fungus also attacks the coffee berries, about one-third of which are found to have blackened grains, the large proportion of such grains indicating that some of the injury is due to Pellicularia. In any event the number of berries attacked is so small that as a berry disease it is of little importance. The loss occasioned by this disease is that which results from the destruction of green leaf tissue, and through this the lessened yield of berries. It is principally a leaf parasite, but also causes the death of young branches, which often die after defoliation. When the branch is not killed it can not again bear leaves until new growth has been made. The tree must be weakened and the yield correspondingly reduced by the loss of foliage. What the loss from this source may be it is impossible to know, but if proportionate to the percentage of leaves killed it would equal more than one-fourth in some trees noticed. The loss of leaves is ordinarily much less and frequently many trees escape infection. The loss in yield of berries from this source in most plantations is not large. It has never been observed to kill the trees. Like the "mancha de hierro," it is rarely found on poor, half-starved trees for the reason, no doubt, that such trees usually are in rather dry situations and have less foliage.

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Various remedies have been tried. The gathering and burning of the diseased leaves sometimes recommended gave poor results. Enough of the fungus remains on the stems to serve to reinfect the plant so that it is soon as badly diseased as before. The lime-sulphur sprays, of which both the boiled and unboiled were used, were ineffective, as was also the sulphur alone applied as powder. Bordeaux mixture is really effective.[1] The fungus can not grow on a leaf covered with this spray, and it adheres better than the other fungicides, especially when made up with twice the usual amount of lime. Owing to the frequent and heavy rains of the wet season even this spray is washed off to some extent after a few days. In attempting to increase the adhesion various substances were added to the mixture, including borax, but the ordinary mixture with merely an extra amount of lime was found to be better than any of these. In the use of any spray material difficulties are met with, among which is that of training the peon to direct the spray so as to cover the lower sides of the leaves and to be thorough in the work, leaving no unsprayed, diseased leaves to serve as centers of infection. On many of the trees reinfection takes place from the pieces of fungus threads which the spray has missed or which have been partly concealed under the bark, making necessary repeated sprayings if the trees are to be kept clean. It is possible to destroy the fungus entirely on some trees by one spraying and to prevent the infection of healthy trees to a large extent, but to exterminate the disease even with repeated sprayings is difficult. The work of one year seemed to indicate that spraying furnished excellent means of checking the disease, but further work has shown it to be less satisfactory than it first appeared. To open up the trees to the wind and air by felling the shade could only have a bad effect on the coffee and is not to be recommended.

As the nearest approach to a good way of controlling the disease Bordeaux mixture made up with 4 pounds of copper sulphate and 8 pounds of unslaked lime or 16 pounds of air-slaked lime to 50 gallons of water applied as spray to the underside of the leaves is recommended. In no event should a larger area be treated than can be conveniently looked over from time to time in order to note any

[1] In case Bordeaux mixture is to be used in any except very small quantities it will be well to make up stock solutions of the required ingredients, and take from these from time to time as needed. In this way it will be always possible to have a freshly made up and effective solution, that having been made up for some time spoiling. The ordinary mixture, 4:4:50 formula, is made by dissolving 8 pounds of the copper sulphate in 25 gallons of water. The lime and water for the other stock solution is made by slaking 8 pounds of live lime, using enough water to form a thin paste and adding to 25 gallons of water. The Bordeaux mixture is made by taking one part of each of the stock solutions, two parts of water, and agitating the mixture thoroughly. It is often convenient to make the mixture in the spray pump. The formula used in the work with coffee differs from the above in having twice the amount of lime, which has the effect of making it adhere somewhat better to the foliage.

reappearance of the disease and resprayed when found necessary. Picking the leaves before the spraying will probably be of some assistance if care is taken to remove as carefully as possible all the threads on the twigs, using for the purpose the cheaper labor sometimes available for picking the berries.

LEAF SPOT (*Stilbella flavida*).

This disease does not seem to be known in Porto Rico by any definite common name, being merely referred to as a spotting of the leaves. In Venezuela and apparently elsewhere on the continent and Central America it is called "mancha de hierro," but no doubt this term is made to include other small spots of both fungus and insect origin. It is quite generally distributed throughout the coffee-growing region of America, having been reported from Mexico, the Antilles, and Brazil. In Porto Rico it is found principally in the higher altitudes, where it is favored by excessive rainfall. Lower down it is found near streams and where it is sheltered from winds and afforded a moist atmosphere during part of the year. It is more dependent on moisture than other coffee fungi, being unable to infect new leaves or to form new fruits except under conditions of extreme humidity.

The disease is characterized by the occurrence on the leaves of small spots usually circular in outline, but sometimes ovoid along the veins. (Pl. II.) The newer ones are very dark, the older ones light colored. The spots are usually about 6 millimeters in diameter, although many of the older ones become 12 to 13 millimeters in diameter. Sometimes they fuse or give entrance to other tissue-destroying fungi which infect the intervening tissue, producing spots of considerable size. The worst affected leaves have from 30 to 40 or even more spots, so that a large proportion of the leaf tissue is destroyed. On the upper surface of many of the spots and also to some extent on the lower surface may be seen hair-like projections from 1 to 4 millimeters long of a yellowish color, each bearing at the end a head so that they resemble minute pins. This is the reproductive or fruiting stage of the fungus. (Pl. VII, A and B.) Each spot produces a continuous crop of these hairs so long as weather conditions are favorable. The total number at any time is small and in an entire season but from 20 to 50 are produced in each spot, judging from the number of old filament bases. The largest number observed was 70 in a spot of 7 millimeters diameter. As the leaf spots become older, growth having stopped for any reason, such as the advent of the dry season, the diseased tissue falls away, leaving numerous circular openings in the leaf. In other leaf diseases the dead tissue remains.

Sometimes the fungus attacks young stems, where it causes conspicuous scars and so weakens the points affected that they are easily broken by the wind. The berries also are attacked, a slight discoloration of the grain being frequently caused.

The microscope shows the filaments, which are solid, not hollow, as sometimes stated, to be made up of the fine fungus threads which are somewhat branched in the upper part to form the head. The ends of the threads are swollen and have sometimes been mistaken for spores when seen in cross section (Pl. VII, B), and described as such. No real spores have ever been found in any of the numerous specimens examined. The fungus is distributed by the heads at the ends of the filaments being caught by the wind or raindrops and carried to near-by leaves, a process facilitated by the heads becoming loosened in the older filaments through the formation of cavities or "lacunæ" near the point of attachment. (Pl. VII, B.) The head is soon fastened to the leaf on which it happens to fall by the numerous threads which it sends out at the point of contact. Within less than a week a dark circular spot is formed and new filaments appear and new loosely attached heads are formed on these by means of which the spread of the disease is continued. Apparently this fungus has no other way of propagating itself, and the writer has not found any other stage of *Stilbella flavida*, all inoculations into coffee with suspected forms resulting negatively. Among other fungi used in such inoculations was one which answers so fully to the descriptions of *Sphærostilbe flavida*[1] that it may be considered identical with that fungus. As *Sphærostilbe flavida* is sometimes referred to as the perfect stage of *Stilbella flavida*, as full use as possible was made of the small amount of material available. This fungus was first found here on a berry, which, with others bearing Stilbella spots, had been sterilized externally and placed in a moist chamber. Later the same fungus was found on a coffee berry still attached to the tree, where several of the Nectria-like fruits had developed in a spot made by Stilbella. These were studied more fully. Direct inoculations of the perithecia into coffee berries did not take. In drop cultures of the ascospores a Cephalosporium developed. In pure cultures from single ascospores this fungus and later a Fusarium developed. This material was used in inoculation both into the berries on the tree and into very thoroughly disinfected and washed berries in flasks. A slight infection resulted on the unpicked berries. On those in the flasks perithecia identical with those from which the ascospores had been taken developed. But in no case did *Stilbella flavida* result from the inoculations. Those made into leaves did not take. The work failed to show any relation between the fungus used in the inoculations and *Stilbella flavida*. Of the

[1] Massee, Roy. Bot. Gard. Kew, Bul. Misc. Inform., 1909, No. 8, pp. 337–341.

large number of berries affected with Stilbella examined no others with Sphærostilbe were found, so that even if it were a stage of Stilbella it could play a very small rôle in the distribution of the disease in this island. If the fungus is a Basidiomycete, as assumed with some reason by Spegazzini,[1] it was not found to possess such a stage.

It is of interest to note that, although the coffee plant is the principal host of this fungus, numerous other plants are also affected to some extent. The writer has found it on such unrelated host plants as the orange, mango, Begonia, various ferns, several of the coitres (*Commelina* spp.), and guava (*Inga vera*), and bejuco de carro (*Velia sicyoides*), and have noticed the spots, but not fruits, on the yautia, banana, and also on several wild plants. The coitres, which are perhaps most affected, and the ferns and other plants of low habit of growth form in many places a continuous ground covering and catch the greater part of the falling propagative bodies which escape the coffee leaves, and are hence peculiarly subject to the disease. They are apparently able to communicate it to unaffected plants of the same kind and doubtless also to healthy coffee plants. There were noticed places where the coffee was not attacked until several weeks after the ground plants had become infected.

When first taking up the study of coffee diseases in Porto Rico the "mancha de hierro" appeared of small importance, for the reason that the area affected is so restricted by climatic conditions. But the regions of the island most affected produce the best coffee, and if it were not for this disease they would give larger yields. The injury to the trees is not so much in the actual amount of the leaf tissue destroyed, although this may amount to one-fifth or even more of the entire amount in the worst cases, but in the defoliations which take place after a time. The diseased leaves drop sooner than those not affected, and owing to the weakened condition of the tree are not soon replaced. After the first severe attack the base of each tree may be seen to be surrounded by a pile of green leaves several inches deep. The disease never kills the trees. They live on with scanty foliage and are able to put forth some new growth and bear a small amount of berries each year.

The decrease in yield following an attack of the leaf spot is marked. In one experimental plat, where a record of the yield had been kept for some years, it was found to be 75 per cent. In this case the difference between the trees before and after the attack was such as accompanies the loss of the greater part of the foliage.

The fungus, Stilbella, also attacks the berries. As mentioned above, however, it does not do very much harm to the fruit—much less, in fact than that caused by the Cercospora fruit spot—for it

[1] Rev. Facult. Agron. y Vet., La Plata, 2 (1896), No. 22, p. 339.

never causes the fleshy part of the berry to adhere to the parchment, in this way making the pulping more difficult. Out of several lots of berries examined, of which all were affected by Stilbella, a varying number, from 6 to 18 per cent, were so badly affected that the discoloration could not be removed in the process of polishing to which coffee is subjected in preparation for the market.

An experiment in the control of this disease was begun at the substation, La Carmelita, to test the efficiency of gathering and destroying the diseased leaves, a method recommended in some publications on this subject. Ten trees in one of the worst diseased areas were selected for this purpose and the leaves with Stilbella spots removed, two rows of the surrounding trees being similarly treated to prevent too immediate reinfection from other trees. The effect of the leaf picking on the prevalence of the fungus was roughly determined by finding the relative proportions of diseased and healthy berries, both being counted, in the trees of the plat and in an equal number of those outside. The proportion of diseased berries in the trees of the plat in the crop immediately following the first picking of leaves was 38 per cent; in the outside trees, 10 per cent. During the year the leaves were picked at intervals of three months. At the end of the year the percentage of diseased berries in the trees with picked leaves had declined to 16 per cent, but in the outside trees had increased to 32 per cent. It is probable that an equally large increase of Stilbella-affected berries would have been found in the trees from which the diseased leaves were picked if it had not been for this treatment, the disease having made great headway in all parts of the plantation.

Further work in combating the disease was made impossible by a change in the management of the plantation where the work was being carried on. However, such results as have been obtained would indicate that the disease might be successfully combated by removing the diseased leaves. No doubt the defoliation so produced is as bad for the tree as that caused by the fungus, but if the work were carefully done the newly formed leaves would remain free from infection, except as they might be gradually reached from trees outside the treated area. The fact that the disease spreads comparatively slowly and that the diseased leaves are readily recognized make this treatment more easily carried out. It would seem that this slow and apparently impracticable method might be really of value in combating the disease where the cheaper labor used on some of the plantations is available.

Spraying with Bordeaux mixture will exterminate the fungus if weather conditions happen to be favorable, but it is almost useless where the disease is most prevalent because of the frequent rains. The fungus can not infect leaves that are not moist much of the

time; and when the leaves are dry, the time that Bordeaux would be most effective by adhering best, the disease is at a standstill, as any of the heads which happen to fall on such leaves do not germinate even if they adhere. The violent downpours soon wash the fungicide from the smooth upper surfaces of the leaves, where it must adhere to be of any effect. Moreover, the hillsides are so steep in many places that only knapsack sprayers could be used, and these only with difficulty. In case spraying is resorted to, it will be of most value when applied to the healthy trees near the diseased ones or to those less severely attacked, for the reason that the spray will prevent the infection of the leaves to which it adheres, though having no effect in preventing the formation of new propagative bodies on the already existing spots.

The disease does not spread with great rapidity. In one case observed it progressed about 200 yards in one year. Many plantings, probably newer ones, are free from this pest, although climatic conditions are such that it could do much damage if once it obtained foothold. After it appears in such places it is merely a matter of time until the entire field is affected, and it is under these conditions, when only a small area is affected, that it can be combated to most advantage. Unless prevented, it will extend down the mountain slopes until it reaches drier conditions, the only obstacles to its progress in other directions being strips of forest or grass land or an especially exposed or unshaded slope. The coffee of the "altura" requires less shade than that of the lower lands, but even there it is seldom that there is an excess of shade. If such exists, it could be lessened to advantage, for anything making for drier conditions is unfavorable to this fungus. To cut the shade away entirely, however, would be a remedy worse than the disease, and one which no experienced grower would try.

ROOT DISEASES.

In many plantations there are to be found places where all the coffee trees have died out, the largest of such treeless areas covering an acre or more. These areas are usually well marked, being surrounded by healthy trees. The death of the trees is due to the action of certain soil fungi which attack the roots, usually the upper ones, and the base of the trunk. The first indication that a tree has been attacked is the drooping and yellowing of the leaves, which later fall, beginning with those of the lower branches. The roots of the trees will be found to be well covered by the thread-like growth of the fungi and partly decayed. There are two types of the disease, which may be classified for convenience according to the color of the accompanying fungi as the black (*Rosellinia* sp.)[1] and white root diseases. The

[1] Apparently *Rosellinia bunodes*.

black type of the disease, which is perhaps the more common, is the one referred to in this bulletin unless otherwise stated, as it has been possible to study it more thoroughly (Pl. III, fig. 1).

The disease having made its appearance in one or more trees extends to the surrounding coffee trees. Its advance, which is very slow, is marked by the dying or dead coffee trees at the edge of the diseased area. In one case, when it was possible to determine the rate of progress fairly readily because of the disease attacking the thick herbaceous undergrowth, it covered from 10 to 12 feet in one year. Usually the growth is less rapid than in this instance. The only things which retard or stop its progress seem to be excessively dry or excessively wet soils, natural barriers, such as brooks, and the scarcity of food material (decaying vegetation) in the soil. The conditions favoring its growth are those provided by moist shaded soils, which usually offer an abundance of food material. Unfortunately, these conditions are also those favorable to the coffee tree, so that the disease often does most harm among the best trees, the sun-exposed dry slopes of poor coffee plantations remaining quite free from the trouble. In more than one instance it has seemed to start with the decay of a stump or tree trunk. As the fungus is known to live on dead vegetable matter, it is probable that these stumps furnish such abundance of food material that it becomes strong enough to attack living plants, whereas ordinarily it merely makes use of the usual decaying material covering the soil in well-shaded places.

In the black form of the disease that part of the trunk just above the surface of the ground becomes covered for a few inches with a thin brown closely adhering coating of the fungus mycelium soon after being attacked. On the roots and parts of the trunk below the surface the mycelium is gathered more into strands of a brown color which later becomes black. Below the thin outer bark the threads form a nearly solid layer, thickly grown together. From this there extends into the bark and wood root-like branches less than 1 millimeter thick. On cutting away the bark and wood these appear as small black dots and lines, according to the angle at which they are cut. These form one of the most characteristic features of the disease. In trees recently killed the fungus will be found to have passed but little deeper than the inner bark, although in old stumps it may penetrate 2 or 3 centimeters. The attack is usually near the surface of the ground, involving the trunk at the surface and sometimes also the uppermost roots. It later advances downward for a few inches, but the deeper roots usually remain uninjured. Occasionally on that part of the fungus growth near the base of the trunk there are formed numerous small hair-like projections 1 to 3 millimeters long. These are light colored at the tips, close together, and have a somewhat brush-like appearance. At first they are evenly

FIG. 1.—COFFEE TREE ATTACKED BY THE ROOT DISEASE FUNGUS (ROSELLINIA SP.).

FIG. 2.—IMPERFECT FORM OF ROOT DISEASE FUNGUS (DEMATOPHORA SP.) ON PETIVERIA PLANTS.

COFFEE LEAVES ATTACKED BY THE ZONAL LEAF SPOT (CEPHALOSPORIUM SP.), SHOWING UPPER AND LOWER SURFACES.

distributed, but later appear in clusters beneath which are formed wart-like outgrowths (sclerotia). The hair-like projections bear minute spores which doubtless serve to distribute the fungus to some extent. (Pl. VIII, B.) This stage of the fungus (Dematophora) is quite common, though produced less frequently on coffee than on many other plants. (Pl. III, fig. 2.) In the sclerotia are sometimes formed other kinds of reproductive bodies that are characteristic of the genus Rosellinia. (Pl. VIII, A.) This seems quite rare, as the writer has found it but twice, once on a wild shrub (*Piper* sp.) and once on coffee.

Among other plants than coffee which this fungus attacks is anamú (*Petiveria alliacea*), a weed quite common among the coffee. It was observed to kill out a thickly growing area of this plant, a grass (palmilla) taking its place. No other plant among the coffee has been found to be injured except young guamás. Once when the fungus escaped from pots of infected coffee plants it destroyed the near-by growing ornamentals, *Graptophyllum pictum*, *Panax plumatum*, and *Acalypha mosaica*. It has been noticed once among the trees and low growths at the edge of a clearing, attacking and killing nearly all the plants with which it came in contact, among which, besides the rose apple, were species of Miconia, Piper, and Palicourea, all of shrubby habit. A Tradescantia, one of the common ground plants in well-shaded coffee, covered the ground as soon as it was cleared by the fungus. A fern (*Adiantum* sp.) seemed to be the only plant able to resist its attacks except the large, thick-barked guamás and mangoes. The fungus left a vegetation quite different from that which it found, causing it to appear somewhat like that of the clearings made for coffee.

Although acting slowly, the losses to coffee produced by root diseases are probably not exceeded by those from any other cause. The injury is greater because the better trees suffer most, especially in the case of the black root disease. The fungus causing this disease is distributed throughout the coffee-growing regions of the island, not being limited by climatic factors as are some other diseases. The places where the trees have been killed are often left for a long time before replanting, and after the trees are reestablished it is several years before they bear fully. Just how long before the ground becomes fit for replanting without treating the soil with some fungicide has not yet been determined, but this probably depends on the amount of food material available to the fungus in the soil. In one case noticed the trees replanted where the vegetation had been killed two years previously have not shown, during a period of eighteen months, any sign of the disease.

Some experiments were made with the hope of finding an effective way of controlling the disease. These have included ditching about

the diseased areas, a method commonly recommended for this sort of disease as a means of preventing the spread of the fungus to uninfected areas, and the treatment of the soil with substances having some degree of fungicidal action. The ditching seemed especially advisable, because the fungus is superficial, never penetrating the soil for more than a few inches. The substances added to the soil included lime, sulphur, chloronaphtholeum, and copper sulphate. These were selected as being fairly easily procured and quite cheap. if not too great quantities should be necessary for their effective use. Other substances used included potassium permanganate and potassium bisulphite. The effect of breaking up the soil by means of heavy hoes, a method quite common in cultivating coffee, was also tried in some of the check plats and in all of the other plats. Previously to this cultivation all diseased trees and stumps and the partly decayed vegetable débris common in such places were removed. For the lime experiment the soil was first broken, after which the lime was applied at the rate of 500 grams per square meter, being thrown into shallow trenches and immediately covered. The trenches being close together and parallel, the application was thorough, no part of the surface being overlooked. The ground was sprinkled with water to slake the lime and then worked with hoes to mix it with the soil. Whenever a diseased tree had been removed an extra amount of lime was added. Similar methods were used in applying the sulphur, care being taken to mix it thoroughly with the soil. Two areas were treated, one receiving 500 grams per square meter, the other about one-fourth of this amount. The chloronaphtholeum, a petroleum distillate product of the same class as carbolineum, was used in one of the worst diseased places. It was applied at the rate of about 50 cubic centimeters per square meter, being poured in 5 per cent solution into small holes which were made about a foot apart. Later the ground was sprayed with this solution and then worked over with hoes to secure more thorough penetration.

During the three years since the experiment was begun no trees have died in plats receiving lime and the heavier application of sulphur. In the check plat adjacent to that receiving lime 6 per cent of the trees have died, and about 3 per cent of the trees in the plat with the smaller application of sulphur and in that receiving the chloronaphtholeum. In a plat of anamú showing this disease an application of chloronaphtholeum amounting to 100 cubic centimeters of the undiluted preparation and another with the excessive amount of 450 cubic centimeters per square meter were made. The heavier application stopped the disease without injuring the healthy plants. The disease was unchecked by the lighter application, all the plants in this plat being killed by the fungus. In any event

treatment with preparations of this nature is not to be considered, as it is ineffective if the smaller quantities are used and its cost prohibits the use of large amounts.

Although the use of lime for this disease promised little, still it had the advantage of being very cheap and readily procured besides being often useful in its effects on the physical condition of the soil. Moreover, if it is even of small merit in combating the disease it is to be recommended, as, being already familiar to the planters, they would use it in preference to other more effective but less common materials. The good results obtained from its use in these field experiments may be partly due to the disinfecting action of the heat of slaking and possibly, also, to lessening the amount of vegetable matter in the soil which could be used by the fungus as food. That the heat generated by slaking may have had some fungicidal effect is further indicated by the fact that when the already slaked lime was used in the form of a thin paste at the rate of 200 grams per square meter on a much-diseased plat of Petiveria no effect in checking the progress of the fungus was to be observed. The use of air-slaked lime is not to be recommended in the case of the black root disease if it is wished to check the disease at once by its application. Its effect will be good only as it tends to improve the soil and hasten somewhat the decomposition of the vegetable matter on which the fungus feeds. Such action in any event will be slow.

The good results from the use of sulphur must be referred to its fungicidal properties. In well-aerated soils sulphur dioxid is probably formed, and hydrogen sulphid in soils excessively moist. Both of these substances have weak action as disinfectants. But it is not unlikely that their continuous production through several months would serve at least to prevent the growth of the fungus and perhaps to destroy it. Additional evidence that some such action exists was obtained by mixing sulphur in the soil with which a trench about 4 inches deep and of equal width was filled, using about 15 grams of sulphur to each meter of the trench. The fungus has killed the plants up to the sulphured soil, but during the entire year on which it has been observed has not passed to the healthy plants on the other side. In part of the ditch which received no sulphur the fungus has passed over and destroyed the Petiveria plants.

In the three years since this work was begun 2 per cent, or 6 out of 317, trees have died in the treated plats, all of these being in the plats receiving the smaller applications of sulphur and chloronaphtholeum. None have died in those treated with the other disinfectants, but the results from the treatment with these substances are of little interest because of their cost. In the check plats which were merely cleaned and ditched 5 per cent, or 16 out of 334, trees

have died. Although it is as yet impossible to arrive at definite conclusions, it would seem that treatment of the soil with some substance rendering conditions unfavorable for the growth of the fungus was of practical value.

As to the cost of materials used, that of lime sufficient for 100 square meters is but 35 cents. The cost of sulphur at the rate used in the experiment would be 10 times as much. However, it would be worth while to use even such remedies if cheaper materials were less successful. If begun while the diseased areas are not too large the expense for such treatment would be small.

As copper sulphate is a substance which is injurious to plant life, except in very small quantity, it was not thought desirable to apply it so freely to the soil as the other substances used. Accordingly it was applied only to the trees near those attacked by Rosellinia. A quantity equivalent to 15 grams of the salt was sprayed about the base of the trees. Within a few weeks the fungus had passed the sprayed trees, killing all the Petiveria except near the coffee trees. The form of the disease that remains in places where the fungus has passed seems to be less virulent, probably because less well nourished. After the copper salt has been washed out by rains the trees so treated will probably be subject to attack from the fungus as soon as enough food material accumulates to give it sufficient start. The spraying of the entire surface with a solution of copper sulphate was tried, the spray being of such concentration as to equal 25 grams of the salt per square meter. This was found in an experiment on 8 square meters of land badly infested with the black-root disease to be sufficient to check and apparently to exterminate the fungus, which has not reappeared during the year which has passed since the spraying. The cost for the copper salt alone used at this rate amounts to 50 cents, at local prices, for a quantity sufficient to treat 100 square meters. Where the drainage is good, as on the clay hillsides, not enough of the copper is retained in the soil to be harmful to vegetation. Under such conditions and on soil suitably cleaned this is an effective remedy. Possibly a considerably smaller quantity of the copper salt would be equally effective. However, since satisfactory results can be secured by other means, the use of copper salts in controlling the disease is not to be recommended.

The work carried on so far would indicate that cleaning the land, ditching, and liming were of value in combating this disease. The cleaning includes the taking up and removal of the diseased and dead coffee trees. The usual custom of cutting off the tops of such trees and leaving the stump to decay is bad. Such material, together with piled-up leaves, branches, and other débris, half-decayed vegetable matter which serves the fungus as food material, should be gathered in the infested places and burned. Large stumps that can not be

removed should be ditched about, if they occur in the diseased areas that are to be treated, as they sometimes seem to harbor the disease. The guava and guamá, which are frequently killed by borers, leave many such stumps, and for this reason these trees are undesirable as shade trees. If the ground is to be broken up, which is an advantage if lime is to be added, this should be done immediately after the cleaning. The ditches should be a foot wide and of somewhat greater depth. Care should be taken to examine the bases of the trunks of all the trees to be inclosed by ditches in order to make sure that no diseased trees have been left inside from which the disease can be communicated to the others. Such an examination will usually show some of the healthiest looking trees to be affected with the disease, often being girdled just below the surface of the soil. The length of time that such trees can live and bear fruit, after having been girdled, is indicated by the fact that a coffee tree of which the bark was removed for a space of 4 inches about the base, the wound having been painted with carbolineum to kill any living tissue from which growth might set up, lived for 23 months, bearing one full and one partial crop. Any tree showing a diseased patch near the crown should be removed. Ditching about the diseased areas, together with the gathering and destruction of the diseased trees and vegetable débris, constitutes the most important step in controlling the disease. After the earth has been broken up unslaked lime may be applied, as already described, care being taken not to place it too close to the trees. If applied in the dry season it should be sprinkled with water to slake it after mixing with the soil. It is not likely that a quantity of unslaked lime less than that used in the experiment (500 grams per square meter) would be effective.

To summarize, ditching is recommended as preventing the fungus from passing from diseased to healthy trees; cleaning up vegetable débris and removal of diseased or dead coffee trees and the addition of lime or some other substance to the soil are measures of some value in combating the fungus. The ditches should be cleaned out from time to time and vegetable material prevented from accumulating in the places affected with the disease. Such measures are of special value where only a few diseased trees are found among otherwise healthy plantings. Where the centers of infection are too numerous it may be useless to protect with ditches and even less so to use the other sanitary measures mentioned above except, perhaps, the removal and destruction of diseased trees as soon as observed.

BERRY SPOT (*Cercospora coffeicola*).

This spot of the berry is troublesome since it causes the fleshy part of the fruit to adhere to the parchment, thus making the process of preparation more difficult. It is also the cause, at least indirectly,

of part of the injury to the grain which results in its being classed as of lower grade.

The fungus causing this spot, *Cercospora coffeicola*, has been reported from Central and South America. Doubtless it occurs throughout the American coffee-growing regions. In Porto Rico it is present to some extent in every plantation. Both leaves and berries are affected by the disease. On the leaves it causes round spots, varying from 6 to 10 millimeters in diameter, of a brownish color somewhat lighter toward the center than at the edge. There are rarely many on any one leaf, and so little harm is done by the fungus as a leaf parasite as to be negligible. On the leaves, however, they produce spores which serve to spread the disease and to carry the fungus over from one crop to another. On the berries the largest spots, those fastening the fleshy part of the fruit to the parchment, almost always are found on the upper side. Any part of the fruit may be attacked, the spots appearing at first as small brown discolorations. They are especially common on the nearly ripe berries. At the time of picking, the larger spots cover about half of the fruit and are velvety with the spore-bearing outgrowths of the fungus.

The occurrence of the largest and worst spots on the upper or sun-exposed side of the berries is to be explained by the fact that the spots develop more rapidly in the somewhat riper tissue of that side, such uneven ripening of the berry being caused by the direct exposure each day to the sun rays. After the berries have become infected this one-sided ripening takes place more rapidly, the berries being black above with the Cercospora spot and still green on the underside. Whether picked at once or left until thoroughly ripe the berry is difficult of preparation and yields a somewhat inferior product. That the riper tissue furnishes more favorable conditions for the fungus is indicated by the more rapid development of the spots produced by inoculation into ripe berries, and the greater number of spots developing on the nearly ripe tissue.

The uniformity with which the upper side of the berries is the part most injured may account for the idea that such berries are injured by hail. As a matter of fact hail is almost unknown at the elevations where the worst affected plantations are situated. Another and better explanation quite commonly given is that the berries are burned by sun either directly or intensified by the lens-like action of drops of water, the disease itself being for this reason sometimes referred to as the "sancocho" of the berries. The presence of an organism, of proved parasitism, even in the earliest stages of the diseased spots, makes these theories untenable. Sunlight is a factor of importance, but only as it influences the development of the spots that happen to occur on the upper side of the berries. These become conspicuous and are thought to be the only ones, the others remaining

unnoticed. There is, however, a small amount of injury to fruits and leaves, not due to parasites, which is to be ascribed to the heat of the sun. On the leaves of unshaded coffee trees such injury is represented by brown shriveled or sunken patches of cells, which in their earliest stages are free from micro-organisms. Occasionally such patches of injured cells form the center of yellowish areas. A similar loss of chlorophyll on the upper side of the berries precedes a premature ripening of the sun-exposed fruit. The berries that ripen thus without being attacked by Cercospora are few in number. That the injury in the case of the leaves is sun produced is indicated by the absence of such "burned" tissue in the leaves of shaded trees and the fact that those leaves with more nearly horizontal or exposed positions are the ones affected. The injury by sunlight is of interest in this connection as it favors infection of the fruits by Cercospora.

Since the existence of a close relationship between the distribution of the disease and conditions as to shade would make possible a practical means of control, it was thought worth while to secure data with regard to this. Accordingly samples were taken from each of the gatherings made in two fields, one with fairly heavy shade, the other exposed to the full sunlight. The quantity of berries examined from each field varied from 132 to 199 liters per season, amounting to from 15 to 20 per cent of the entire yield. The conditions as to soil and slope were fairly uniform in each, so that the samples may be taken as representing the quality of output fairly well. For two years determinations were made of the proportion of Cercospora-spotted berries, including spots of 1 millimeter in length or more. It was found to vary according to the degree of maturity of the samples examined, but reached for the last year 73 per cent for the shaded and 70 per cent of such berries for the sun exposed. It was concluded that, so far as the actual distribution of the disease goes, it is not influenced largely by differences with regard to light. The relative occurrence of the more troublesome or "sancocho" form of the spots was quite different as, in the determinations made the following year, when there were taken only berries in which the spots were sufficiently developed to be blackened and dried to the cascara, it was found to be 16 per cent in the shaded and 27 in the unshaded coffee.

It is well known that there is considerable variation in the quality of coffee, one of the characters of an inferior grade being the larger proportion of blackened and shriveled grains. As it was thought the Cercospora spot of the berry might be the cause of such grains, at least indirectly, the spotted berries, used in the work already mentioned, were subjected to the usual process of preparing the grain. In the case of those used in the earlier work, where even slightly

spotted berries were included, only those of which the parchment was found, in the course of preparation, to be injured or seriously discolored were selected for the final preparation, such parchment being taken as corresponding to the larger, deeper Cercospora spots. Those with sound parchment were not considered farther except to be measured, as it was thought that sound berries or those slightly spotted would give only good grains. Later it was found that some of the injury to the parchment on the berries selected for final preparation was due to merely mechanical injury of the pulping machine. Moreover, it was found that a certain proportion of the sound berries contained bad grains. The results are for this reason not given in full, although they give as uniform and pronounced differences in favor of the product of the shaded trees as the later, more accurate work. Of the grains with any sort of injury the percentage was 33 for the unshaded trees and 19 for the shaded the first year, and the following year 29 and 20 per cent, respectively.

During the last season in which this work was carried on only the more severely attacked berries or those in which some effect on the grain seemed possible were used, the slightly affected ones being classed with the sound berries. The proportion of imperfect grains of all sorts was determined, and of these the blackened ones were separated and also determined. The results given in percentages are as follows:

The effect of shade on the quality of the grain.

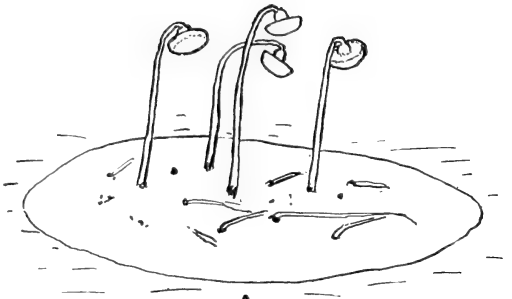
	Shaded.	Unshaded.
	Per cent.	*Per cent.*
All injured grains in good berries	4.5	19.0
Blackened grains in good berries	2.0	11.0
All injured grains in badly spotted berries	27.0	45.0
Blackened grains in badly spotted berries	9.0	36.0

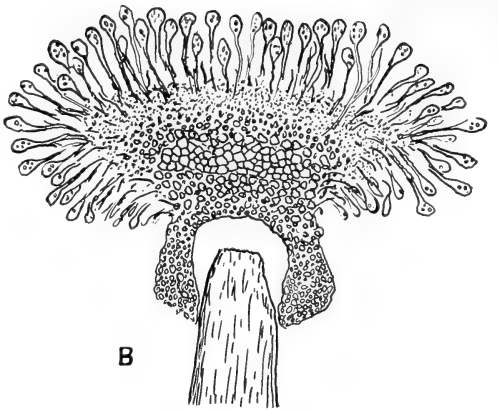
It is evident that the berries more severely spotted by Cercospora contain a greater proportion of bad grains than the unspotted, indicating that the fungus does influence the quality of the grain unfavorably. That the sound-appearing berries should give so much inferior grain or any at all is surprising and not yet well understood. The larger proportion of bad grains in the Cercospora-affected berries from the unshaded field is in accordance with the greater abundance of the more severely attacked berries generally apparent in such conditions. The results show in every instance, whether from spotted or sound berries, a smaller proportion of bad grains to be produced from the shaded field.

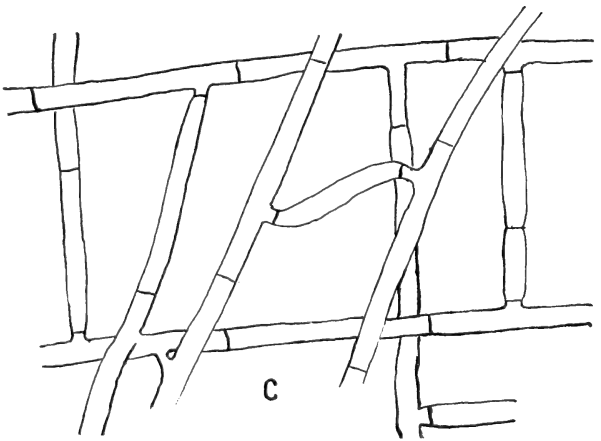
It is clear that Cercospora has nothing to do with a considerable proportion of the inferior grains, since they occur in sound berries. It has never been found among the organisms isolated from the grains

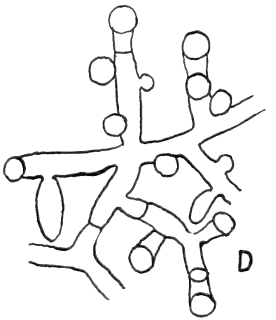
TRUNK OF COFFEE TREE WITH FUSARIUM DISEASE PRODUCED BY INOCULATION.

ROOT OF COFFEE TREE. ROUGHENED BARK DUE TO NEMATODES. ROOTS KILLED BY "WHITE" ROOT FUNGUS.

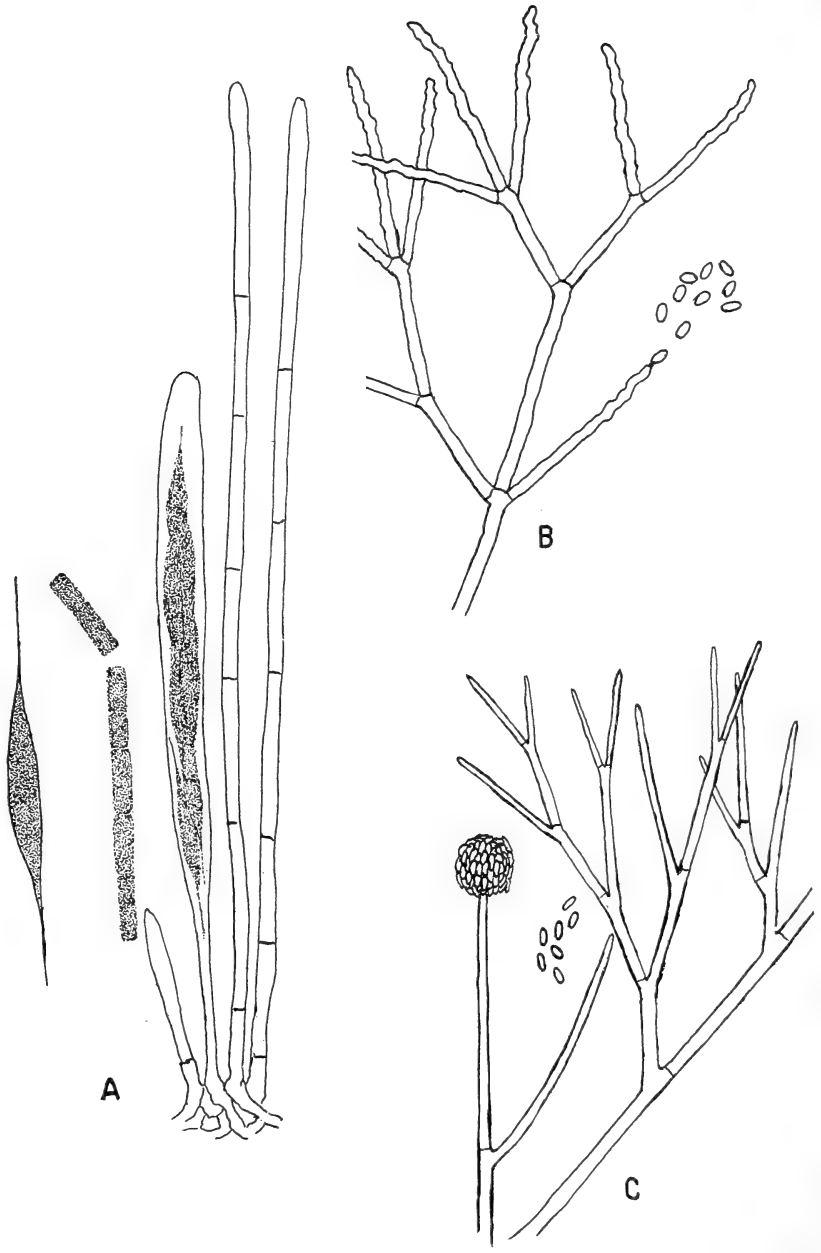








A.—Spot on Leaf Showing Fruiting Bodies of Stilbella flavida (×12). B.—Enlarged Head of Fruiting Body of Stilbella flavida. C and D.—Threads of Pellicularia koleroga, Showing Branching (×450).



A.—ASCUS AND SPORES OF ROSELLINIA SP. (×450). B.—HYPHÆ AND SPORES OF DEMATOPHORA SP. (×450). C.—HYPHÆ AND SPORES OF CEPHALOSPORIUM SP. (×450).

of these berries nor from those of the spotted berries. Such injurious effect as it may have on the grain must be due to the shrinkage resulting from increased loss of water from the spotted fruits, as well as the admittance through the weakened tissue, at the point attacked, of other organisms which attack the grain directly. Of these several have so far been found, the most common being a Fusarium, identical, apparently, with this stage of the Sphærostilbe, already mentioned. The injury resulting from the spot seems to depend on the age of the fruit attacked. When the infection takes place on undeveloped fruits the resulting injury is greater, but if the grain has begun to harden before the spot develops fully it may escape injury.

Another source of the inferior quality of coffee from sun-exposed fields is to be found in the "granos vanos," berries that seem to be well filled out and good, but which are easily recognized at the time of picking by their yielding readily to the pressure of the hand and also by the dried, blackened pedicels. The name could be applied as well to the sound-appearing berries with bad grains mentioned above, but for convenience it is here used to indicate those the injury to which is due to the supply of food material having been cut off, as shown by the dead pedicels. Not isolated berries alone, but often all on one branch or the entire tree are affected in this way. The shriveled grain contained in these berries remains free from fungi or bacteria for a long time, the injury being clearly not due to these organisms. The blackened tissue of the branch at the base of the pedicels always contains a Glœsporium, and occasionally a Fusarium. But neither of these fungi was found to be able to attack the tissue of healthy green branches when tried out by inoculations with pure cultures. It would seem that they are only able to attack weakened trees exposed to full sunlight and subject to the unfavorable soil conditions accompanying such exposure. Not all the trees in unfavorable conditions produced berries of this sort. What the proportion may be was not determined, but it is only large in the first picking. This was omitted in the earlier work, and in that of the last year the "granos vanos" were separated out, so that the result can not be affected to any extent by their presence in the samples. The hormiguilla (*Myrmelachista* sp.) is to some extent the cause of these "empty berries," as it often injures the base of the fruit-bearing branches and sometimes the pedicels, thus cutting off their supply of food.

It is known that the soil in well-shaded places is more uniformly moist than in more exposed situations, and no doubt the benefit of shade in coffee is in part due to better soil conditions, especially with regard to moisture. The soil in unshaded places becomes very dry in the season of little rains and also very hard where of the clay type. The unfavorable condition as to moisture is made worse by the pres-

ence of grasses which always come in where shade is lacking. The trees in these places are slender, with few branches and but little foliage. The leaves of the branches on which berries set fall when these are half grown and the branches begin to die back at the tips. Where the blackening extends rapidly, killing the bark and pedicels, the "granos vanos" result. The trees, which are dependent on new branches for leaves and berries, are able to form but few of these. A product of inferior quality results, owing to the action of certain diseases of the fruits and grain, thus increasing the loss caused by lessened yield.

STUDIES OF THE SPOT FUNGUS.

It is desired to include at this place something of the technical part of the study. In attempting to determine definitely the nature of the organism producing the spots, the earliest stages of the spots were studied. The berries with such spots were first sterilized and then introduced into the medium, or the spot itself was cut out and introduced into the medium, using the usual precautions. When the sterilization had consisted in washing the berries for three minutes in 90 per cent alcohol, then placing them in 4 per cent formalin for three minutes, and finally washing in sterilized water, the spotted berries usually gave, in addition to a sterile gray fungus, a Glœosporium, while the check unspotted berries similarly sterilized often gave a Glœosporium. With less severe sterilization a Fusarium was often obtained in addition to the above. Later work, with more thorough sterilization, gave only the sterile fungus from the spots. Both the Fusarium and the Glœosporium were tested in inoculations, but without positive results. The sterile fungus was used in inoculations, with the results that typical spots were produced on which Cercospora spores later developed. In the checks small pieces of sterile absorbent cotton of about the same size as the pieces of mycelium were introduced into small wounds, the purpose being roughly to duplicate the conditions of the inoculation. No infection resulted in the case of those checks, although the chances of such infection from natural sources existed. No attempt to sterilize the berries on the trees before this inoculation was made, and the results showed it to be unnecessary. From the spots resulting from the inoculation the usual gray sterile fungus was reisolated.

No spores of Cercospora were borne on the mycelium in artificial culture. However, on some of the mycelium placed on the berries but slightly introduced into the wound, abundant spores of Cercospora were in one instance produced. The material used in the inoculations of the following season was obtained from spores developing on typical spots of the berries. The spores, because of their comparatively large size, are easily isolated from drop cultures. The

germinating spores were transferred directly from the agar of these cultures to the usual media. In every case the typical gray sterile mycelium, similar in every way to that used in the inoculations of the preceding year, resulted. This when inoculated into the berries produced the usual spots from which it was reisolated, and there can thus be no doubt as to the identity of the organism producing this spot. An attempt was made to show that the spot on the berry could be produced by spores from the leaf spots. When transferred directly from the leaves to the berries no infection resulted. Later pure cultures from the spores of the Cercospora of the leaf were obtained, as in the case of that of the berry. The resulting growth, which was similar in every way to that in cultures of the berry fungus, when inoculated into the berries, gave positive results, typical Cercospora spores later developing.

In conclusion it may be said that the spot of the berries produced by *Cercospora coffeicola*, which besides interfering with the preparation by causing the flesh to dry and adhere to the berry also injures the grain to some extent, may be largely prevented by the use of sufficient shade, as, for example, that of sufficient density to prevent the growth of grasses other than palmilla. Such shade is distinctly favorable to the production of coffee free from inferior shrunken grains.

MISCELLANEOUS DISEASES.

Of less importance but perhaps worth mentioning in any general discussion of coffee diseases are the "zoned" leaf spot and a root and trunk disease. The leaf spot is characterized by its tendency to develop concentric rings, such rings being sometimes incomplete at the outside of the spot, and often beginning as entirely separate spots which increase until united with the central mass (Pl. IV). On the underside of the older spots a thin white mold appears after a while, which is condensed or massed in places. This bears the numerous spores of the fungus (*Cephalosporium* sp.) (Pl. VIII, C.) which has been shown to be the cause of the spot by isolation from the beginning spots and by inoculations from pure culture. The disease is common among the best coffee, seeming to prefer the young and well-shaded leaves, and all the various species and varieties cultivated at this station are subject to attack, though it is most common on the "Ceylon Hybrid." It has been noticed on other plantations but is nowhere abundant.

Another disease is easily recognized by the smaller diameter of the affected part of the trunk owing to the bark drying up and shrinking (Pl. V). After being diseased for a long time the bark falls away leaving the wood exposed and the calloused outgrowths at the edge of the healthy bark. If the diseased bark is cut away

the wood will be found to be blackened as if somewhat charred. A fungus, *Fusarium* sp., is always present in the diseased tissue, but inoculations with pure cultures have failed to produce the disease. It is communicated readily to healthy trunks by means of small pieces of diseased material, and when thus transferred has shown itself to be rapidly developing and destructive, soon killing the living tissue for several inches above and below the point of inoculation.

Infection appears to take place through wounds, as, for example, the stumps left by cutting off part of the branches close to the ground. It frequently accompanies the "white" root disease, attacking the yet living trunk above the diseased roots. It seems probable that it can attack the tree near the crown through small wounds such as those made by the machete in weeding, but no clear evidence of this has been found. The characteristic Fusarium was isolated from a decorticating disease of coffee where all the trees were attacked at some 2 or 3 feet from the ground. In this case ants and mealy bugs were also present, so that the injury was probably due in the first place to these insects. The decorticated branches with the enlarged outgrowths of healthy tissue at the base of the branches occasionally to be seen are no doubt the after effects of this form of the trunk disease.

The foregoing includes all the commoner and more destructive Porto Rican coffee diseases produced by fungi. One disease, that caused by *Hemileia vastatrix*, which is said to have caused so much damage to the cultivation of this plant in India and the East Indies, does not occur here and has not been reported from any American coffee-growing country. The threadworm *Heterodera radicicola*, is often active in trees suffering from root disease, being found in such cases at the upper edge of the diseased area at the base of the trunk (Pl. VI). It was thought at first that it might be the real cause of the white-root disease, but since specimens have been found free from this worm there can be no necessary relation between the two. It attacks the bases of the trunk, however, causing them to take on a roughened, somewhat swollen appearance for a foot or so above the soil. When cut into with a knife there may be seen, even with the naked eye, the minute globular bodies of the adult females, by which such diseased tissue is characterized. No real evidence that the trees are really injured by this disease has been noticed. The characteristic swellings caused on roots by this worm may sometimes be seen on the fine roots near the surface. The heavy nature of most Porto Rican coffee soils no doubt prevents it from becoming the pest which it sometimes is elsewhere.

SUMMARY.

(1) For leaf rot (*Pellicularia koleroga*) there has been found no really satisfactory method of control. The benefit of repeated sprayings with Bordeaux mixture is lessened by the fact that the fungus is not all killed even by repeated sprayings, enough remaining to reinfect the trees after a time.

(2) For leaf spot (*Stilbella flavida*) Bordeaux mixture is really effective, and it may be recommended to prevent the disease from extending to healthy and productive plantings.

(3) Cercospora spot of the berries, which causes the more badly affected berries to be pulped with difficulty, and also injures the grain to some extent, is to be prevented in its worst form by providing sufficient shade, which by rendering less harmful this and other sources of injury to the grain decidedly improves the quality of the output.

(4) The root disease may be prevented from spreading by ditching, this being preceded by the removal and destruction of vegetable débris, diseased trees, and stumps. It is apparent that the addition of unslaked lime, sulphur, and some other substances to the soil prevents the growth of the fungus causing the disease.

(5) Importance is to be placed on the use of preventive measures to keep the still healthy younger plantings in good condition rather than on attempts to exterminate the diseases among the older trees.

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